Claims

1. A method of transmitting and receiving multiple RF/microwave subcarriers on a single optical wavelength over an optical link comprising the steps of:

modulating a plurality of RF/microwave subcarrier frequencies with a respective communication signal;

modulating an optical carrier wave with the plurality of modulated RF/microwave subcarrier frequencies;

detecting the plurality of RF/microwave subcarriers of the optical carrier wave and mixing those subcarriers with a first local oscillator (LO) frequency to create a new heterodyne IF frequency above the highest frequency component of the modulated signal spectrum of the detected subcarriers;

filtering an RF/microwave subcarrier frequency of the plurality of detected RF/microwave subcarriers utilizing a bandpass filter at an IF center frequency of the new IF frequency; and

mixing the filtered RF/microwave subcarrier with a second local oscillator (LO) frequency to derive a difference frequency at a desired center frequency for propagation over the subsequent network element.

2. A method of transmitting and receiving multiple RF/microwave subcarriers on several closely spaced optical wavelengths comprising the steps of:

producing a plurality of RF/microwave subcarrier frequencies;

modulating each of the plurality of RF/microwave subcarrier frequencies with a plurality of information signals;

modulating each of a plurality of individual optical signals with at least some modulated subcarriers of the plurality of modulated RF/microwave subcarriers;

stabilizing the plurality of optical carrier signals to known optical frequencies;

mixing the plurality of optical signals at the receiver with a local oscillator (LO) laser tuned to a known optical frequency such that a heterodyne beat note between the LO laser and a carrier frequency corresponding to a desired signal component is at a center frequency of an IF above a highest frequency component of a modulated signal spectrum of the plurality of RF/microwave subcarriers;

filtering a limited bandwidth of RF/microwave subcarrier frequencies utilizing a bandpass filter at the IF center frequency to provide a filtered IF output; and

mixing the filtered IF output with a local oscillator to derive a difference frequency at the desired center frequency for propagation over a downstream network element.

3. A method of transmitting and receiving multiple RF/microwave subcarriers on a single optical wavelength over an optical link comprising the steps of:

modulating a series of communications signals onto a series of RF/microwave subcarrier frequencies;

restricting a RF modulation bandwidth of the series of RF/microwave subcarrier frequencies such that mixing of a detected RF spectrum with a local oscillator (LO) frequency to create a new heterodyne IF

frequency in a desired frequency band causes the difference frequencies of one detected band that occur at a same frequency as the sum frequencies from another band to fall outside the desired frequency band;

modulating a single optical carrier wave by a full spectrum of RF/microwave signals defined by the modulated series of RF/microwave subcarrier frequencies;

detecting the full spectrum of RF/microwave subcarrier frequencies and mixing those subcarrier frequencies with the LO to create a new heterodyne IF frequency in the desired frequency band for propagation over a subsequent network element;

filtering the detected RF/microwave subcarrier frequencies at a desired center frequency of the desired frequency band by utilizing a bandpass filter at the IF center frequency (or any other type of filter) that eliminates those frequencies at which difference frequencies of one detected band may occur at a same frequency as sum frequencies from another band over a full range of desired LO frequencies.

4. A method of transmitting and receiving multiple RF/microwave subcarriers on several closely spaced optical wavelengths comprising the steps of:

modulating a series of communication signals on a series of RF/microwave subcarrier frequencies;

modulating each of several individual optical sources by independent and exclusive series of communication signals so that each optical frequency carries a full spectrum of RF/microwave signals comprising the series of subcarrier frequencies;

restricting an RF modulation bandwidth such that mixing of an optical signal spectrum with an optical frequency to create a new heterodyne IF frequency in the desired frequency band causes difference frequencies of one detected band that occur at a same frequency as sum frequencies from another band to fall outside of the desired frequency band;

stabilizing the multiple optical carrier signals to known optical frequencies;

mixing the optical signal at a receiver with a local oscillator (LO) laser tuned to a known optical frequency to create a new heterodyne IF frequency in the desired frequency band for propagation over the subsequent network element; and

filtering the RF/microwave subcarrier frequencies at a desired center frequency of the new IF frequency by utilizing a bandpass filter at the IF center frequency (or any other type of filter) that rejects those frequencies at which the difference frequencies of one detected band may occur at the same frequency as the sum frequencies from another band over the full range of desired LO frequencies.

5. A method of using a local oscillator laser for heterodyne detection and for eliminating polarization dependent loss by compensating for polarization mode dispersion in the single mode fiber transmission link comprising the steps of:

separating two orthogonal linear polarization optical components of an input optical signal utilizing a polarizing beamsplitter, said input optical signal

arriving at a first port of the polarizing beamsplitter;

introducing a local oscillator laser into a second input port of the polarizing beamsplitter;

providing two polarization maintaining optical fibers from the polarizing beamsplitter through a polarization maintaining optical coupler, said two optical fibers having substantially a 50% coupling ratio within the optical coupler and a known optical length such that corresponding optical path lengths of the two fibers from the input to the polarizing beamsplitter to a beginning of a coupling regime of the optical coupler are equal;

aligning the two orthogonal linear polarization outputs within the two polarization maintaining optical fibers to a common polarization axis by rotating one of the fibers through an angle of ninety degrees so that the orthogonal polarization outputs of the polarizing beam splitter excite the same polarization axis of each polarization maintaining fiber; and

aligning each of the polarization maintaining fiber outputs from the polarization maintaining fiber coupler to independent photodiode based receivers.

6. A method of remotely locating a local oscillator laser for heterodyne detection utilizing single mode fiber without incurring polarization dependent loss within a coupling regime due to polarization mode dispersion in the single mode fiber comprising the steps of:

separating two orthogonal linear polarization components of an optical signal arriving at a first

input port of a polarizing beamsplitter within the polarizing beamsplitter;

introducing a local oscillator laser into a second input port of the polarizing beamsplitter;

providing two polarization maintaining output fibers from the polarizing beamsplitter through a polarizing maintaining optical coupler, said optical coupler maintaining substantially a fifty percent coupling ratio among the two coupled fibers and the two fibers having a known optical length such that corresponding optical path lengths from the input of the polarizing beamsplitter to a beginning of a coupling regime of the optical coupler are equal;

aligning two orthogonal polarization outputs within two polarization maintaining fibers to a common polarization axis by rotating one of the polarization maintaining fibers through an angle of ninety degrees so that the orthogonal polarization outputs from the polarizing beamsplitter excite the same polarization axis of each polarization maintaining fiber;

splicing one or both of the polarization maintaining fiber outputs from the polarization maintaining fiber coupler to a single mode fiber to provide single mode fiber outputs; and

aligning each single mode fiber output to a photodiode based receiver.

7. A method of remotely locating a local oscillator and optically combining an optical output of the local oscillator with a signal field for heterodyne detection using single mode fiber without incurring polarization dependent loss due to polarization mode dispersion in

the single mode fiber, such method comprising the steps of:

combining the signal field and the optical output of the local oscillator in a single mode fiber coupler;

directing the combined signal field and optical output into a first input of a polarizing beamsplitter and separating two orthogonal linear polarization components of the combined optical signal field and optical output within the polarizing beamsplitter;

maintaining two polarization maintaining fibers between the polarizing beamsplitter and a polarizing maintaining coupler with fifth percent coupling ratio to a known optical length such that the two optical path lengths of the two polarization maintaining fibers from the input to the polarizing beamsplitter to the beginning of a coupling regime of the polarizing maintaining coupler are equal;

aligning the two orthogonal linear polarization output components from the polarizing beamsplitter to a common axis of the two polarization maintaining fibers by rotating one of the two polarization maintaining fibers through an angle of ninety degrees; and

aligning the polarization maintaining fiber outputs from the polarization maintaining fiber coupler to independent photodiode based receivers using polarization maintaining or single mode fibers.

8. A method of receiving up to four sets of independent signals on each microwave subcarrier frequency carried by an optical transmission signal, such method comprising the steps of:

modulating the independent communication signals on upper and lower sidebands of two independent microwave signals of the same frequency;

modulating the two independent microwave signals on the upper and lower sidebands of the optical signal respectively;

introducing a local oscillator laser in a correct polarization state to eliminate polarization dependent loss relative to a received optical signal;

tuning the local oscillator laser to the wavelength below (or above) the wavelength of the optical carrier to select the upper (or lower) optical sideband creating a heterodyne beat note at an intermediate frequency;

filtering the heterodyne beat note utilizing a bandpass filter with a bandwidth suitable for selecting an individual microwave sideband;

making a center frequency of the bandpass filter offset from the intermediate frequency so that the center frequency corresponds to the upper (or lower) microwave sideband relative to the selected microwave sideband; and

mixing the filtered intermediate frequency output with a local oscillator frequency to shift the center frequency of the filtered microwave sideband to the correct frequency for propagation over a downstream network element.